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The summary below is contributed by H.A. Stone

High speed video and the formation of emulsions using microfluidic devices

We have developed a novel microfluidic device for the formation of water-oil and oil-water emulsions (this research is supported by Unilever). In particular, we have used a "flow-focusing" concept to generate small drops of one liquid phase by flowing a second liquid phase in a sheath around it, and focusing the two liquid streams through a small orifice (see figure below). In some cases the droplets formed have an approximate size set by the orifice and in other cases (depending on the flow rate of the external phase as well as on the ratio of the two flow rates), the droplets can be much smaller than the flow rates. This research was performed by Dr. Shelley Anna, a postdoc in my group, and Nathalie Bontoux, a visiting undergraduate from Ecole Polytechnique in Paris.

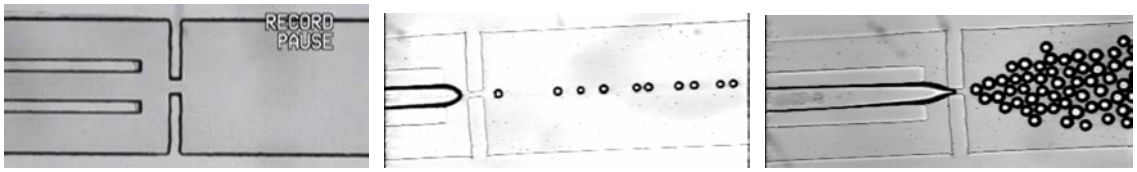

Figure: (a) Flow focusing geometry implemented in a microfluidic device. A wall containing an orifice is placed a distance H_{focus} (here, 200μm) downstream of three coaxial inlet streams. Water flows in the central channel and oil flows in the two outer channels. The orifice has a diameter of 43 microns. (b) Experimental image of drops formed as a thread of water is focused through the orifice. In this example, flow rate of oil is $Q_{oil}=4.0x10^{-2}$ mL/min and the ratio of flow rates is $Q_{oil}/Q_{water}=100$. (c) Experimental image of drops formed at a lower oil flow rate ($Q_{oil}=0.5x10^{-2}$ mL/min) in which the two flow rates are more similar ($Q_{oil}/Q_{water}=2$).

With NSF support we acquired a high-speed video camera that has been crucial to characterizing and understanding the physics of the drop formation process in these small channels. In addition, we are collaborating with Professor David Weitz and his postdoc Darren Link on ways to breakup drops in microchannels, which provides control of drop sizes and drop size distributions. The high-speed video is invaluable for measurement and understanding these flows.

Education, Outreach and Mentoring during 2002 [the highlights below reflect contributions by H.A. Stone; the efforts were assisted by Professor C. Friend (Harvard), R. Graham, MRSEC Coordinator (Harvard), and had the additional support of D. Weitz, MRSEC Director (Harvard)]

During the Spring 2002, with the support of the Harvard MRSEC and NSEC programs, I visited two Historically Black Colleges and Universities and I also visited the University of Maryland, Baltimore County,[1] which has excellent students and programs supporting talented minority students. The goal of the visits, as well as follow-up email and phone call contacts, was to establish links with the science and engineering programs at these schools. The visits were very successful. This summer four students from HSCBU's joined the Harvard REU Summer program. Three of these students[2] worked on research projects in my laboratory and did very well. I was very happy with their progress and I think they learned a lot as well.

In addition, I gave one evening seminar to the REU students, participated in a luncheon attended by minority students doing research in the MRSEC and NSEC programs, and participated in other student activities as well. The MRSEC Director Professor David Weitz and Associate Director Professor Cyndy Friend have been supportive throughout and they also made presentations over the summer to the REU students.

During the summer of 2001 I worked with a Cornell undergraduate, Leo Shmuylovich, who was part of the 2001 MRSEC REU program at Harvard. Leo was lead author of a paper that appeared in Langmuir.[3]

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[1] I visited Howard University with R. Graham and I visited Morgan State University and UMBC with Professor C. Friend.

[2] Harold Nykail (Howard University), Ashika Severin (Morgan State University) and Lisette Williams (Xavier University)

[3] L. Shmuylovich, A.Q. Shen and H.A. Stone, "Surface morphology of drying latex films: Multiple ring formation," *Langmuir* **18**, 3441-5 (2002); highlighted in "Editor's Choice" *Science* **296**, 619 (2002).